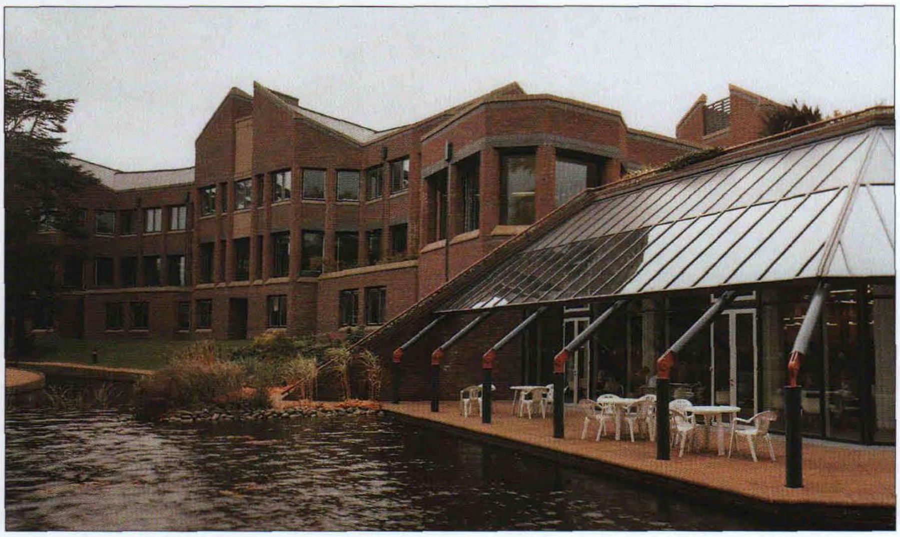
Case Study 20

Energy efficiency in offices

Refuge House, Wilmslow, Cheshire
New owner occupied offices designed for both natural ventilation and air conditioning

- Courtyard form avoids excessively deep spaces
- Thermal capacity of structure limits summertime temperatures
- Underfloor air conditioning with openable windows permits various operational modes
- Flat structural ceilings with high intensity uplighting
- Air heat recovery and waterside free cooling systems
- Comprehensive electronic energy management and controls



The Project

When Refuge Assurance decided to vacate their Victorian offices in the centre of Manchester, they obtained a parkland site on the outskirts of Wilmslow. While wanting to make the best of natural light, ventilation and view, Refuge also needed the flexibility and capacity to accommodate changing organisational needs, a mix of cellular and open offices, and modern information technology.

The offices are therefore designed with both natural and mechanical systems available. A courtyard form gives a compact plan with depths of 12 or 15 metres, allowing most people to be near a window; generous openable windows provide both light and air; and tall ceilings with exposed soffits assist cross-ventilation and provide thermal capacity to help limit peak temperatures.

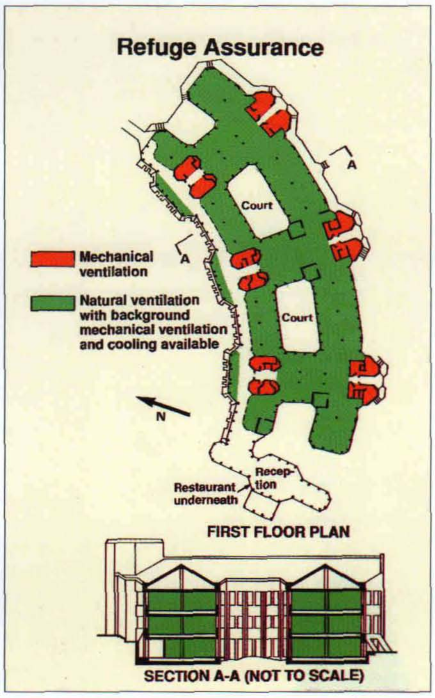
This attractive environment is supported on a raised floor which incorporates comprehensive electrical, heating, cooling and ventilation systems with extensive computer control.

The Result

The building has worked well in meeting Refuge Assurance's needs and obtained the Institute of Administrative Management's Office of the Year Award 1989. The good thermal performance of the fabric has limited summertime temperatures and cooling requirements. Because the air conditioning does not run everywhere all the time, energy costs are much lower than for most fully air conditioned buildings.

The combination of natural and mechanical systems has not been without its problems, particularly in hot weather when people are uncertain whether to open the windows or to rely upon the air conditioning. Some energy waste occurs but not enough to be significant. Interlocks were considered at the design stage but were rejected on grounds of cost and reliability.

The building demonstrates that it is possible to enjoy the advantages of both natural ventilation and air conditioning, and hence be able to operate in the most energy efficient manner consistent with the required environment.



> *"Good environmental conditions achieved at low energy costs for this head office"*

Energy Efficiency Office
DEPARTMENT OF THE ENVIRONMENT

REFUGE HOUSE

Overview

The main offices have openable windows and underfloor fan-coil air conditioning, taking low temperature hot water (LTHW) and chilled water from central plant on the ground floor. Controls for the 400 fan coil units are each individually addressable from the Landis and Gyr Visonik Electronic Building and Energy Management Systems (BEMS), allowing cooling and heating to be provided only in areas where it is needed or requested.

Heating

Three 600kW gas-fired boilers supply a primary LTHW circuit to which three separate pumped circuits are connected:

- Weather compensated for underfloor fan-coil units and radiators on stairs etc.
- Weather compensated for air handling plants.
- Constant temperature for hot water.

The systems operate under optimum start/stop control to deal with the varying requirements throughout the year.

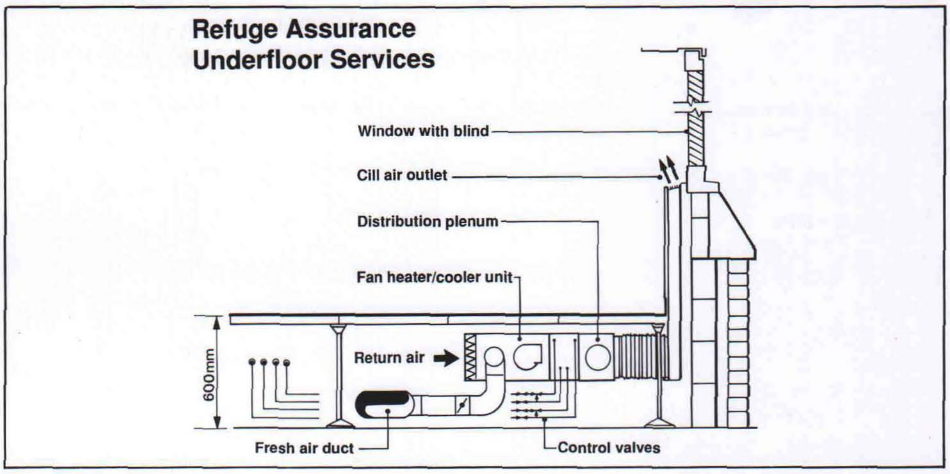
Domestic Hot Water

The domestic hot water is heated by the boilers (described above), and stored in calorifiers. There are two calorifiers in the boiler room for the toilets and two for the main kitchen.

The reason a separate water system was not installed was because the designers assumed that the main boilers would be operational for most of the working day to meet air conditioning needs. As it happens, heat is not normally required for some four months in the year.

Refrigeration Plant

Two screw chillers provide chilled water for the offices, (the computer system is serviced separately). In cool weather (with lower outside temperatures and less cooling demand) the chillers are switched off and "free" evaporative cooling is obtained from the cooling tower, via a plate heat exchanger. This reduces annual energy consumption for refrigeration by at least one-third.



Underfloor Services

Ventilation and Air Conditioning

Fresh air, heated or cooled as necessary, is supplied to the offices from six packaged air handling units in plant rooms under the pitched roof. The air is ducted through the floor voids to the individual fan coil units (see schematic) and withdrawn via the floor plenum. The fresh air supply rate of 1.2 air changes per hour can be doubled if necessary. The windows can also be opened.

The underfloor 4-pipe fan-coil units have 3-speed fans (normally at medium or low speed), filters, and heating and cooling coils each with 3-port motorised valves. Most units are near the perimeter and blow air up via short ducts to grilles at window cills. Units in the centre, about 50 in all, have floor supply diffusers.

Toilet ventilation is by six packaged supply/extract plants in the roof space, each with LTHW heater batteries and cross-flow heat exchangers.

The kitchen, computer room and internal service areas have separate tempered fresh air supply plants, plus a cassette air conditioner in the post room which gets crowded at sorting times. The main and ancillary dining areas have constant volume air conditioning plants.

Lighting

Good daylight is available from the generously-sized (about 40% measured internally) double glazed tilt-and-turn aluminium windows, with splayed reveals and mid-pane venetian blinds for glare control. The form and orientation of the building provides some solar shading, with an open aspect to the north and west and trees and banks to the south and east.

Office lighting is by specially designed 250 watt metal halide uplighters, normally wall and column mounted, with a few supplementary free-standing units. Elsewhere lighting is normally fluorescent with some decorative low voltage tungsten halogen.

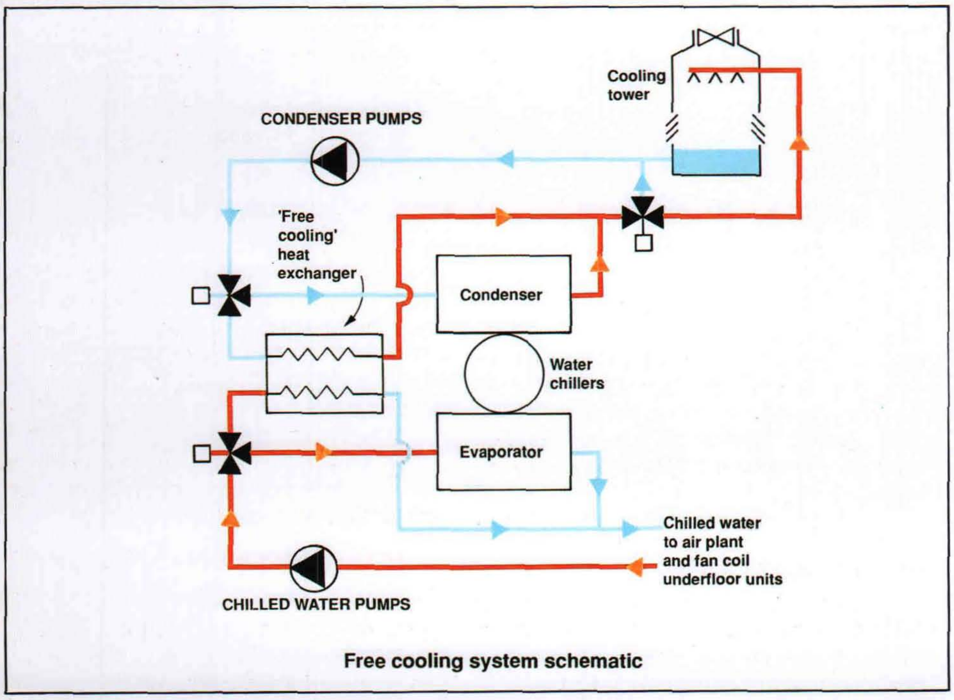
Controls

Direct digital controls are by the central BEMS. With some 3000 points, the system is potentially daunting but has proved easy to operate by careful design, good management, standardised plant, and common schedules for similar items.

Lighting is automatically controlled by an independent system, also linked to the BEMS. The lights in the circulation areas operate to a time schedule, while perimeter lights are normally switched on by occupants and off automatically at the end of the day and at lunchtime in summer.

Computer Room

The 206m² computer room is independently cooled by chilled water downflow room units with electric steam humidifiers and electric heat. For the period covered by this case study, the chilled water return was pre-cooled via a plate heat exchanger and a cooling tower. This reduced the chiller energy consumption. Recently however, a growth in the computer system has meant that the 'free cooling' tower has been required to service an additional chiller. It is hoped that sometime in the future computers will become less energy intensive and free cooling can be restored.



Free cooling system schematic

Catering

Some 400 meals per day are served in the ground floor air conditioned dining room from a commercial kitchen with a mixture of gas and electrical equipment and an all-electric servery.

Building Team

Designers:	Building Design Partnership
Builder:	Laing Management Contracting
Mechanical Installation:	Haden Young
Electrical Installation:	N G Bailey & Co.

Building Details

Purpose-built office, completed 1987

Floors:	Ground + 2 + attic space for plant
Gross floor area	17820m² 191750ft²
Treated floor area	13600m² 146400ft²
Nett floor area	9900m² 106600ft²
Typical number of occupants:	700
Typical hours of use:	8am-6pm weekdays plus some weekend and evening work.

Fabric	U-value (W/m²K)
Walls brick-clad cavity-insulated	0.6
Roof (including attic)	0.4
Windows (aluminium double glazed)	3.3
Solar protection:	overshadowing, orientation and mid-pane venetian blinds.

Heating & Hot Water

Gas boilers 3 × 600kW

Separate weather compensated zoned circuits for underfloor fan-coil units and for air handling plants. Optimum start/stop for occupancy hours. Boilers available during occupancy times throughout the year.

Constant temperature circuit for twin domestic hot water calorifiers for toilets etc. and a similar pair for main kitchen.

Ventilation and Air Conditioning

Heated and cooled fresh air supplies (1.2 air changes per hour) to 400 underfloor 4 pipe fan-coil units in offices. Openable windows also available.

Separate constant volume air conditioning to dining area. Heat-recovery mechanical ventilation to toilets.

2 × 360kW (output) screw chillers with cooling tower and plate heat exchanger for "free cooling" outside the summer season.

Computer suite has 2 × 120kW water-cooled chillers and downflow room AHUs.

Lighting

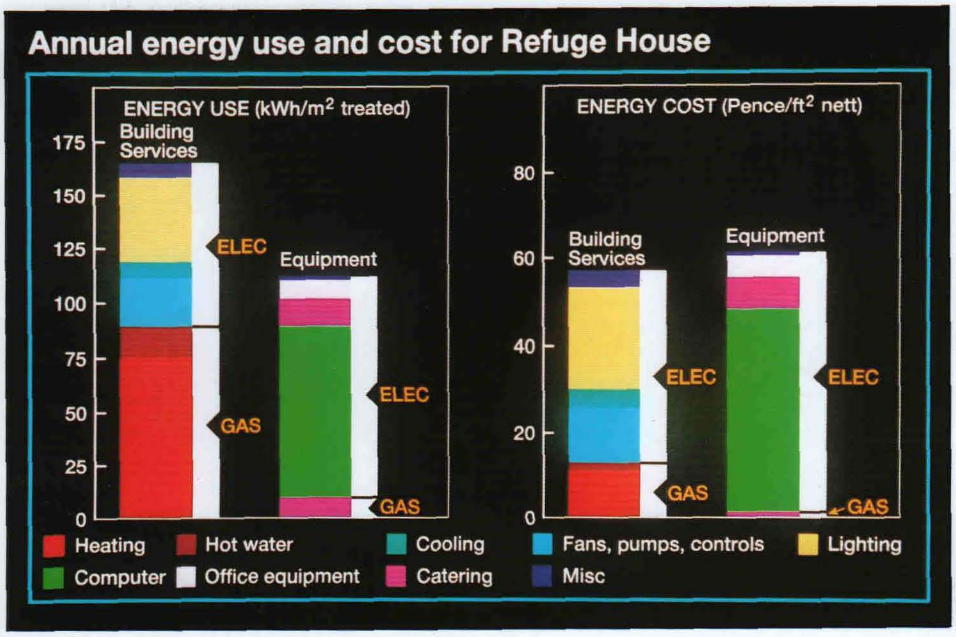
Well-controlled daylight to perimeter.

Metal halide office uplights 400 lux
Office installed load 19 W/m²

Fluorescent lights elsewhere with some tungsten halogen decorative lighting.

Energy Management

Central direct digital control by Landis & Gyr Visonik BEMS and intelligent outstations. Lighting control by ECS Ltd, linked to BEMS.



Analysis of Energy Use and Energy Cost

The diagram above shows the breakdown of annual energy use and cost.

From August 1988 to July 1989 (2183 degree days) the building consumed 1,356,000kWh of gas and 2,400,000kWh of electricity, costing £15,500 and £109,500 respectively: 14.5 and 103 pence per square foot nett. 43% of the electricity is used in the computer suite: when this is deducted the total of 196kWh/m² of treated area is 25% below the CIBSE Energy Code Part 4's "good" level for an air conditioned office of this size. With catering and office equipment removed it comes well into the "good" category for a naturally ventilated office.

Nevertheless, the overall consumption is similar to that for well managed air conditioned buildings with minimum fresh air supplies and fan-coil or unit heat pump systems (see for example the Quadrant House Case Study in this series).

■ Heating **75kWh/m²**

This is relatively low, particularly as heat is available to the air handling and fan coil units (under BEMS control) for all but 2 months in the year. With a more conventional 7-month heating season, energy consumption would have been some 10% less, though possibly with some discomfort early on some mornings.

■ Hot Water **14.5kWh/m²**

Gas consumption is relatively high owing to heavy use in the kitchens, which account for nearly 75% of this figure.

■ Cooling **8kWh/m²**

Cooling energy consumption is creditably low, particularly in the hot 1989 summer, illustrating the energy saving potential of natural ventilation and "free" cooling systems in suitably designed buildings with good management and effective control.

■ Fans, Pumps & Controls **22kWh/m²**

The main component is the fans (15kWh/m²), of which the kitchen and restaurant systems account for nearly one-third owing to relatively high pressure drops and long running hours.

□ Lighting **39kWh/m²**

Although not unreasonable for this quality of building, lighting energy consumption is higher than the designers had anticipated, owing to increased running hours, particularly in the offices and restaurant. The metal halide office uplighters take several minutes to warm up (and about ten minutes to start again after a power interruption) and so they tend to be switched on ahead of occupancy and stay on "just-in-case".

■ Computer Suite **80kWh/m²**

The computer installation has been growing rapidly and in 1988-89 it had three times the power requirement of the 1985 design estimate. Recent addition of another 50% may increase consumption disproportionately as the "free cooling" system has had to be abandoned.

□ Office Equipment **8.5kWh/m²**

This is an average level. Although there is quite a high level of information technology, many are terminals with a low unit energy consumption.

■ Catering **22kWh/m²**
12kWh/m² electric

This is a high figure, indicating considerable scope for improved energy management by the catering contractors.

■ Miscellaneous **7kWh/m²**

About half this is attributable to external lighting for the extensive site. The rest is split between lifts, fountains, telephone and security systems.

User Reactions

The move from a city centre to an out of town site did not initially suit everybody, but very soon the attractions of the building, its facilities and the landscape became apparent.

By and large occupants were well satisfied with the environment in their new office building. Not unusually however, there were several opportunities to improve matters further.

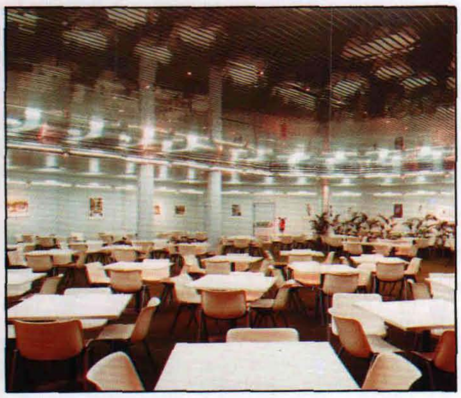
While the ability to open or not to open windows is appreciated, users needed to learn to respond in the most appropriate manner to changing requirements. For example, in hot weather the natural impulse is to open the windows, instead of keeping them shut and relying upon the cooling system.

Routine maintenance and filter-changing of the underfloor fan-coil units is proving unexpectedly onerous, largely because furniture and floor tiles have to be moved to get to them.

Many occupants consider that the tilt-and-turn window mechanisms do not provide sufficient fine control of natural ventilation. The window falls open to the "tilt" position without intermediate stops, giving too much ventilation in cold or windy weather. The inward-opening "turn" position — intended for window-cleaning — is also used for ventilation in warm weather, when the windows can blow about in the breeze and the cooling system is undermined.

The restaurant is a largely windowless, artificially-lit space. People pass along the edge of it to the coffee lounge, which is open all day, and if the restaurant lights are off or dim, the approach to it is unpleasantly gloomy. The restaurant lights are therefore left on for about three times as long as anticipated.

While the local switches on every uplight in the office are appreciated, the long run-up times of the lamps are not. Local switching off is also impossible without visiting every light: otherwise one has to wait for the automatic system.



The Restaurant

General Appraisal

Refuge House has succeeded in its aim of providing a high quality flexible building with good thermal properties and offering a choice between natural and mechanical methods of environmental control. Combined with sound engineering and good management (assisted by the BEMS), good environmental conditions have been achieved at low energy costs for a head office of this type. Nevertheless, there is still scope for further improvement, as described below.

In spite of the good daylight and automatic control system, lighting energy consumption has been higher than anticipated (with a consequent reduction in heating requirements owing to the higher internal gains).

Apart from the unusual problem in the restaurant (which might possibly have been resolved by changes to the building plan), increased lighting use largely arises from the characteristics of the metal halide lamps in the office uplighters. These take several minutes to warm up and even longer to re-strike after being switched off, so people are disinclined to switch off when leaving if they — or somebody else might be coming back. Fittings incorporating tungsten-halogen "starter" lamps might well have solved this problem, but they would have cost more.

Some aspects of the controls have also increased lighting hours, particularly the inability to switch off groups of lights locally and switching all circulation lighting in one block from reception. The controls are now being improved.

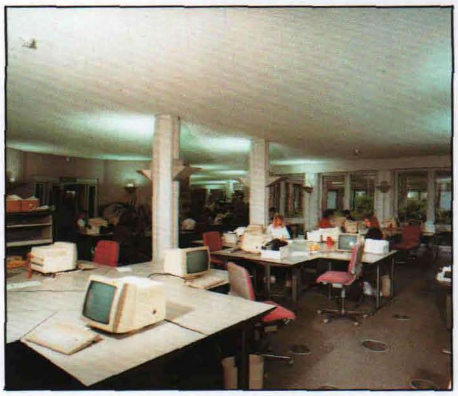
Such control and user issues are a neglected area and require more attention, particularly for buildings such as this which allow many combinations of natural and mechanical systems, local and central control.

Main Conclusions

Air conditioning has become a standard feature in most new head offices for a variety of reasons: from air pollution to prestige. However, at the same time growing health and environmental concerns are raising questions about the real need for sealed highly serviced buildings, particularly away from noisy or polluted town centre sites.

People usually see a straight choice between natural ventilation and air conditioning, and choose the latter because they fear that otherwise it will not be possible to provide year-round comfort and to remove unwanted heat gains from office equipment and so on.

But in the UK — with suitable building design — natural ventilation, assisted perhaps by background mechanical ventilation, may suffice for most parts of many offices for much of the year. Only in certain places and at certain times will cooling be necessary.



Office interior showing floor grilles

At Refuge the designers felt that mechanical cooling might be required anywhere to cope with a growing population of electronic equipment, uncertainly located. At the same time, they saw the merits in environmental and energy terms of a naturally ventilated building on this particular site. So they provided both, giving their client choice, flexibility and low running costs, at a similar capital cost to a conventional fully air conditioned building of a similar quality.

Experience from most of the BRECSU/EEO case studies to date has indicated that electricity use and heat gains are often lower than anticipated from simple examination of individual equipment ratings. Offices designed with efficient lighting and good thermal stability have had lower summertime temperatures and required less cooling than was expected.

While confirming this, Refuge also demonstrates the potential for "mixed mode" buildings, which can be serviced in more than one way, rather than being designed exclusively for natural ventilation or mechanical ventilation and cooling. The Refuge solution features sensible use of the cooling systems which are available throughout. However this approach could be improved further. For example, it may be possible to make less initial cooling provision while providing facilities for upgrading later should this prove necessary.

Short Notes on the Measurement of Floor Area

Gross	Total building area measured inside external walls.
Nett	Gross area less common areas and ancillary spaces. Agent's lettable floor area.
Treated	Gross area less plant rooms and other areas (eg stores), not directly heated.

PRECISE DEFINITIONS ARE AVAILABLE ON REQUEST

All case study analyses in this series are based on at least one year's measured fuel consumption and cost. Further breakdown into sub-headings is by a combination of sub-meter readings, on-site measurements and professional judgement. The technique of apportionment is the same for each Case Study and all quoted building areas have been re-measured for the project.

This study has been carried out by the Davis Langdon & Everest Consultancy Group and William Bordass Associates. The cooperation of the owners, designers, managers and the occupants of the Case Study building is gratefully acknowledged.

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